An American National Standard

Standard Practices for Determining Moisture-Related Acceptability of Concrete Floors to Receive Moisture-Sensitive Finishes[1]

This standard is issued under the fixed designation E 1907; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These practices include both quantitative and qualitative procedures used to determine the amount of water or water vapor present in or emitting from concrete slabs and criteria for evaluating the moisture-related acceptability of concrete slabs to receive moisture-sensitive manufactured finish products, including certain types of resilient flooring (see Terminology F 141), carpet tiles, carpet, and wood flooring, as well as related adhesives.

1.2 Although coatings, films, and paints are not specifically intended to be included in the category of "moisture sensitive finishes" the procedures included in these practices may be useful for evaluating the moisture-related acceptability of concrete slabs for such finishes.

1.3 These practices do not cover the adequacy of a concrete floor to perform its structural requirements.

1.4 These practices do not include procedures to determine the presence of non-moisture related impediments to the application of finishes.

1.5 These practices do not supersede the specific instructions or recommendations of manufacturers for their flooring finishes.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

C 125 Terminology Relating to Concrete and Concrete Aggregates[2]

C 168 Terminology Relating to Thermal Insulating Materials[3]

C 330 Specification for Lightweight Aggregate for Structural Concrete[2]

C 332 Specification for Lightweight Aggregate for Insulating Concrete[2]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[4]

D 4259 Practice for Abrading Concrete[5]

D 4263 Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method[5]

D 4397 Specification for Polyethylene Sheeting for Construction, Industrial, and Agricultural Applications[6]

E 631 Terminology of Building Constructions[7]

E 1643 Practice for Installation of Water Vapor Retarders Used in Contact with Earth or Granular Fill Under Concrete Slabs[7]

E 1745 Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs[7]

F 141 Terminology Relating to Resilient Floor Coverings[8]

2.2 *Other Sources:*

BS 5325:1983 British Standard Code of Practice for Installation of Textile Floor Coverings[9]

BS 8203:1987 British Standard Code of Practice for Installation of Sheet and Tile Flooring[9]

CRI 104-1994, Standard for Installation of Commercial Textile Floorcovering Materials[10]

Addressing Moisture Related Problems Relevant to Resilient Floor Coverings Installed Over Concrete[11]

Moisture Guidelines for the Floor Covering Industry[12]

3. Terminology

3.1 *Definitions:*

3.1.1 For terms used in these procedures, see Terminologies C 168, E 631 and F 141.

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[1] These practices are under the jurisdiction of ASTM CommitteeF06 on Resilient Floor Coverings and are the direct responsibility of Subcommittee F06.40 on Practices.

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[2] *Annual Book of ASTM Standards,* Vol 04.02.

[3] *Annual Book of ASTM Standards,* Vol 04.06.

[4] *Annual Book of ASTM Standards,* Vol 04.08.

[5] *Annual Book of ASTM Standards,* Vol 06.02.

[6] *Annual Book of ASTM Standards,* Vol 08.03.

[7] *Annual Book of ASTM Standards,* Vol 04.11

[8] *Annual Book of ASTM Standards,* Vol 15.04.

[9] British Standards Institution, 389 Chiswick High Road, London W4 4AL.

[10] The Carpet and Rug Institute, P.O. Box 2048, Dalton, GA 30722-2048, 706/278-3176, 1994.

[11] Resilient Floor Covering Institute, 966 Hungerford Drive, Suite 12-B, Rockville, MD 20850 (301) 340-8580, November 1995.

[12] World Floor Covering Association, 2211 E. Howell Avenue, Anaheim, CA 92806 (800) 624-6880 Fax (714) 978-6066, undated but received August 1995.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *mat,* as in "mat test"—a sample of vapor-retardant sheet resilient floor finish material

3.2.2 *moisture emission*—a term used by the flooring industry in the U.S. to measure moisture emission from concrete floors in lb/[1,000 $ft^2 \cdot$ 24 h] (56.51 $\mu g/(s \cdot m^2)$) using the anhydrous calcium chloride test.

3.2.3 *concrete*—concrete made using hydraulic cement as defined in Terminology C 125.

4. Summary of Practice

4.1 This document describes eight procedures, commonly referred to as "tests," used in the construction industry to determine if unacceptable moisture is present in or being emitted from concrete slabs.

5. Significance and Use

5.1 These practices are intended to be used by applicators of moisture-sensitive floor finish products to determine if there are moisture-related conditions existing in concrete slabs which would adversely impact the successful application and performance of these products.

5.2 These practices can also be used as an aid in the diagnosis of performance failures in moisture-sensitive floor finish products.

5.3 Although these practices are called "tests" for conformity with accepted and familiar industry nomenclature, they are intended to be used only in concert with the judgment and experience of the user. One or more of the practices may be referenced in a floor finish application specification only to establish the procedures the specifier intends the applicator to utilize in assessing the acceptability of a concrete surface for a particular finish product.

5.4 Unless otherwise indicated, these practices are applicable to slabs on grade, slabs below grade, and slabs above grade (see Terminology F 141).

6. Interferences

6.1 Conduct procedures after the internal conditions of the building in which a slab is located have been at normal service temperature and humidity for at least 48 h. Otherwise, results may not accurately reflect the amount of moisture which is present in the slab or would normally be emitted from or through the concrete during normal operating conditions. If the service temperature and humidity is unattainable, the internal conditions of the building in which a slab is located shall have been maintained within the following temperature and humidity range for at least 48 h:

6.1.1 Temperature: 65° to 85°F (18° to 29°C), and

6.1.2 Relatively humidity: 40% to 60%.

6.2 No visible water in liquid form shall be present on the concrete at the time procedures commence.

6.3 Avoid locations in direct sunlight or subject to direct sources of heat.

6.4 The concrete surface shall be free of coatings, finishes, dirt, curing compounds, or other substances which may affect the rate of moisture dissipation or the adhesion of finishes. Non-chemical methods, such as abrasive cleaning or bead-blasting, including methods described in Practice D 4259, may be used on existing slabs with deleterious residues to achieve an appropriate state for testing. Cleaning, if required, shall take place a minimum of 48 h prior to testing.

6.5 When using procedures involving electronic instruments, the presence of chlorides or carbonates, whether present as deliberate additions or otherwise, and other concrete additives or metallic fibers can result in erroneous readings. The error will depend on the quantity present but, in general, the water content indicated by the test will be the maximum water content.

7. Procedures

7.1 *General*:

7.1.1 Perform bond and moisture testing procedures on concrete to determine if surfaces are sufficiently dry and free from deleterious substances.

7.1.2 Measure ambient temperature and relative humidity within the structure in which the floor is located at beginning and completion of each procedure.

7.1.3 Sampling

7.1.3.1 Unless otherwise indicated, sampling shall be as follows:

7.1.3.2 Locations shall not be concentrated and shall be distributed around the floor area. One location shall be near the center with others around the perimeter. Selection of locations shall include, but not be limited to, areas of potentially high moisture such as joints and areas closer than 5 ft (1.5 m) from the edge of the slab.[13]

7.1.3.3 Use three sample locations for areas up to 500 ft^2(50 m^2)

7.1.3.4 Use one additional sample location for each additional 500 ft^2(50m^2).

7.2 *Polyethylene Sheet Test*:

7.2.1 *Summary of Method*—This method uses a vapor-retardant plastic sheet sealed to the floor as a vapor trap to determine if excessive moisture is present.

7.2.2 *Significance and Use*:

7.2.2.1 See Section 5.

7.2.2.2 This method, described by Test Method D 4263, was developed by Committee D-33 on Protective Coatings and Lining Work for Power Generating Facilities. It is the responsibility of Subcommittee D33.05 on Surface Preparation.

7.2.2.3 Although developed for coating systems preparation, it is also widely used in the flooring industry.

7.2.3 *Apparatus*—none.

7.2.4 *Reagents and Materials*:

7.2.4.1 Transparent polyethylene sheet Specification D 4397, minimum 4 mils (0.1 mm) thick.

7.2.4.2 Adhesive tape that will adhere to the floor and the sheet, such as duct tape, 2 in (50 mm) wide.

7.2.5 *Preparation of Apparatus*—none.

7.2.6 *Calibration and Standardization*—none.

7.2.7 *Procedure*:

[13] Placement in a grid array is recommended when an isoplethic analysis is anticipated in order to facilitate documentation and accuracy.

7.2.7.1 Tape a plastic sheet approximately 18 in. by 18 in. (460 mm by 460 mm) tightly to the concrete surface making sure all edges are sealed.

7.2.7.2 After a minimum of 16 h[14], remove the plastic sheet and inspect the underside of the sheet and the concrete surface for presence of moisture.

7.2.8 *Calculation and Interpretation of Results*—Presence of visible liquid water indicates concrete is insufficiently dry for application of finishes.

7.3 *Mat Test*:

7.3.1 *Summary of Method*:

7.3.1.1 This method uses a sample of vapor retardant floor finish material and a water-based adhesive to predict the behavior of moisture-sensitive adhesives.

7.3.2 A variation of this procedure (known as the "bond" test) beyond the scope of this document can be used to test for bond between substrate and floor finish products such as vinyl composition tile, PVC backed carpet, and sheet vinyl.

7.3.3 *Apparatus*—None.

7.3.4 *Reagents and Materials*:

7.3.4.1 Latex multipurpose or water soluble adhesive intended for use with resilient flooring products. It is not necessary to use the type of floor finish product intended for application in this procedure, since the sheet product simply provides a vapor-retardant surface which has sufficient rigidity and weight to remain in place during the procedure.

7.3.4.2 Sheet vinyl, or similar resilient vapor-retardant resilient flooring sheet product.

7.3.4.3 Adhesive tape that will adhere to the floor and the sheet, such as duct tape, 2 in (50 mm) wide.

7.3.5 *Preparation of Apparatus*—Prepare number of mats as required approximately 24 in. by 24 in. (600 mm by 600 mm).

7.3.6 *Calibration and Standardization*—None

7.3.7 *Procedure*—Apply adhesive to an area 24 in. by 24 in. (600 mm by 600 mm). While the adhesive is wet, place the mat, surface or face down, immediately into the adhesive. Seal the perimeter edges using tape. The face is placed down to avoid absorption of water in the adhesive by the backing.

7.3.8 *Calculation or Interpretation of Results*:

7.3.8.1 After 72 h, make a visual inspection to determine the condition of the adhesive.

7.3.8.2 If the adhesive is partially or completely dissolved, is still wet, or has little bond, there is too much moisture present to proceed with the installation of flooring material.

7.3.8.3 If the mat is firmly bonded, or removal of the mat reveals the adhesive to be stringy and with good adhesion, the level of moisture present is considered to be sufficiently low for installation of flooring material.

7.4 *Electrical Resistance Test*:

7.4.1 *Summary of Method*—Determines the moisture content by measuring the electrical conductivity of concrete between the meter probes.[15] Conductivity varies in proportion to moisture content. Uses proprietary meters and interpretive methods provided by meter manufacturers.

7.4.2 *Significance and Use*—see Section 5.

7.4.3 This procedure provides a relatively quick way to obtain an approximation of the moisture content of concrete.

7.4.4 *Apparatus*—Suitable instrument to measure the conductivity between two electrodes which are placed in contact with the concrete floor surface or placed into two pre-drilled holes one inch (25 mm) deep into the concrete floor.

7.4.5 *Reagents and Materials*—none.

7.4.6 *Preparation of Apparatus*—Follow instrument manufacturer's instructions.

7.4.7 *Calibration and Standardization*—Follow instrument manufacturer's instructions

7.4.8 *Procedure*—To use one type of instrument, it is necessary to drill holes in the slab to receive pins. Another type can be used with or without drilling holes, but the readings will be more accurate if holes are drilled and the pins are driven into the holes. Care shall be taken to avoid contact between the probes and any metal incorporated into the slab.

7.4.9 *Calculation or Interpretation of Results*:

7.4.9.1 Generic data to correlate measured electrical resistance to acceptable moisture conditions are not available at this time; however, instrument manufacturers generally publish guides for this purpose specific to the instruments they manufacture.

7.4.9.2 Although a high reading (good conductance) typically indicates high moisture content, a low reading (poor conductance) does not necessarily indicate more than surface dryness, as the concrete may have a higher moisture content below the surface. Conversely, a concrete with low moisture content but containing metal fibers could cause a high reading.

7.4.9.3 Confirmation measurements can be made by taking readings at a number of locations which are then covered by a vapor retarder material such as polyethylene sheeting then taking subsequent readings 24 h later after removing the covers. Where the second reading significantly exceeds the first, it indicates that the concrete has an unacceptable level of moisture.

7.5 *Electrical Impedance Test*:

7.5.1 *Summary of Method*—Uses proprietary meters and interpretive methods provided by meter manufacturers to determine the moisture content of concrete by measuring both conductance and capacitance.

7.5.2 *Significance and Use*—See Section 5.

7.5.2.1 A quick, non-destructive way to determine the moisture content of concrete by measuring the electrical AC impedance. Impedance is an alternating current measurement combining both resistance and capacitance while at the same time overcoming the separate limitations of each (single-line measurement with resistance and shallow depth of penetration of signal with capacitance). With impedance measurement, a

[14] Although Test Method D 4263 specifies 16 h, some authorities recommend a minimum of 24 h.

[15] The most detailed information on this test comes from British Standards Institution (BSI) BS 5325:1983 British Standard Code of Practice for Installation of Textile Floor Coverings and BS 8203:1987 British Standard Code of Practice for Installation of Sheet and Tile Flooring.

field is set up consisting of an area under the footprint of the instrument electrodes (Fig. 1). The depth of the signal penetration will vary depending on the material content of the slab and the moisture content, generally varying from 0.75 in. (20 mm) to 2.0 in. (50 mm).

7.5.3 *Apparatus*—An electrical impedance meter specifically developed and calibrated for concrete moisture measurement.

7.5.4 *Reagents and Materials*—none.

7.5.5 *Preparation of Apparatus*—See instrument manufacturer's instructions.

7.5.6 *Calibration and Standardization*—See instrument manufacturer's instructions.

7.5.7 *Procedure*—Follow instrument manufacturer's instructions. Typically, the meter is placed on the concrete slab with its electrodes pressed in direct contact with the surface. When the meter is switched on, low frequency signals are transmitted into the slab, measuring the change in impedance brought about by the presence and level of moisture. The impedance is converted to a percentage moisture content displayed on the instrument dial in both percentage and relative readings. Holes in the slab are typically not required.

7.5.8 *Calculation or Interpretation of Results*:

7.5.8.1 See instrument manufacturer's instructions.

7.5.8.2 Instructions for calibration of instruments and correlation of impedance meter readings to other methods of

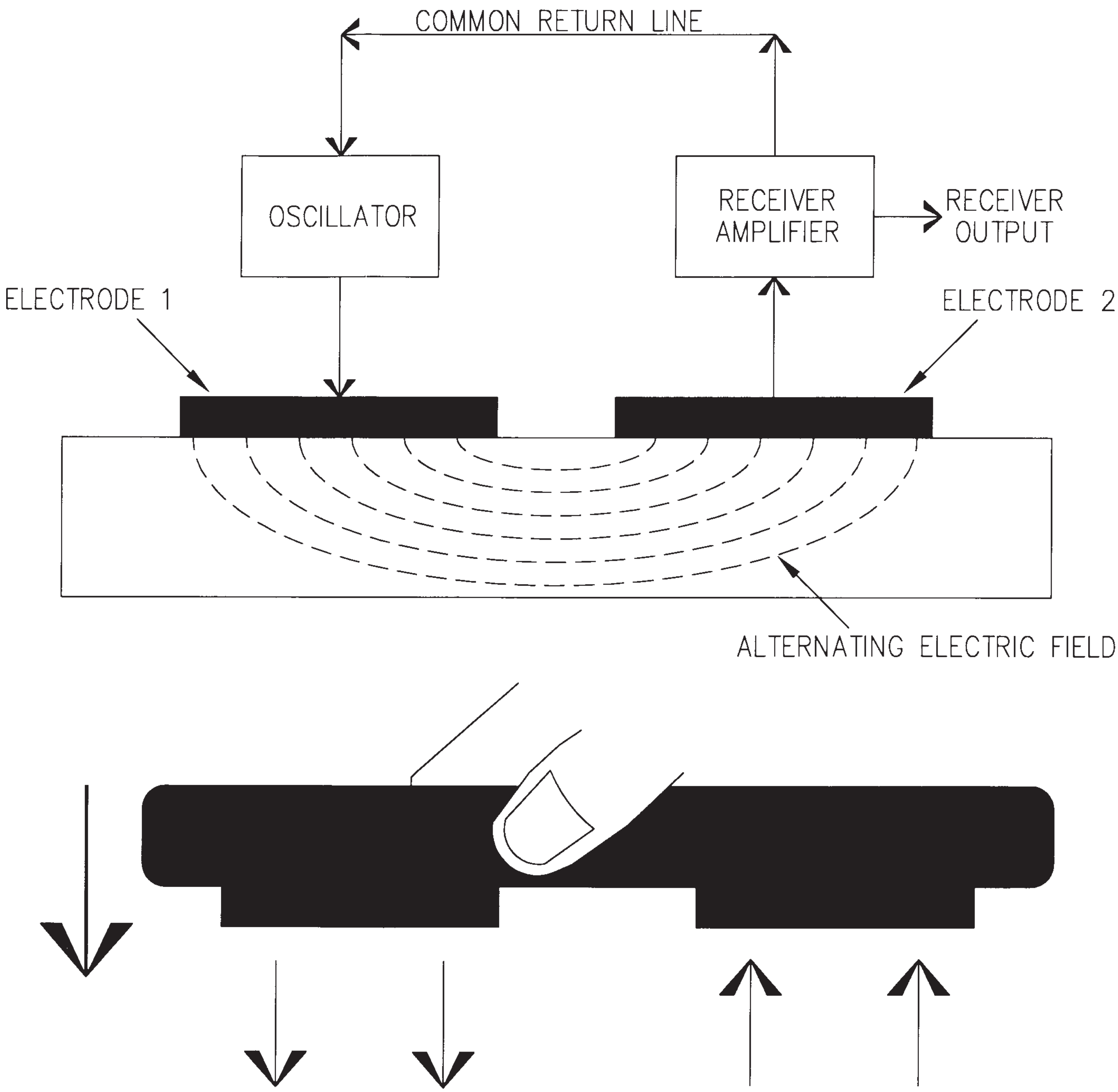

FIG. 1 Basic Schematic of Electrical Impedance Moisture Meter

determining concrete moisture conditions are typically provided by instrument manufacturers.

7.5.8.3 Readings typically indicate percentage moisture content (by mass).

7.5.8.4 Confirmation measurements can be made by taking readings at a number of locations in close proximity to one another. If the readings vary, always use the highest value. Additional confirmation measurements can be made by taking readings at locations which are subsequently covered with a vapor retarder (such as polyethylene sheet), then taking subsequent readings 24 h later. Where the second reading significantly exceeds the first, the concrete is considered to have an unacceptable level of moisture.

7.6 *Qualitative Anhydrous Calcium Chloride Test*:

7.6.1 *Summary of Method*—Detects moisture emission by observing changes in anhydrous calcium chloride ($CaCl_2$) during a specific period of time. A container of anhydrous calcium chloride is exposed to the atmosphere adjacent to a concrete floor under a vapor-retardant canopy.

7.6.2 *Apparatus*—A transparent, hole-free plastic canopy square or circular in shape about 70-100 in^2(450-650 cm^2) in area and depth greater than the depth of the cylindrical container of anhydrous calcium chloride, and with 0.5 in (12 mm) flanges around the perimeter of the cover.

7.6.3 *Reagents and Materials*:

7.6.3.1 One container of anhydrous calcium chloride, tape-sealed in the container against moisture or heat-sealed in an air-tight bag to prevent moisture absorption (Fig. 2).

7.6.3.2 A pressure sensitive label to be used to identify the location of the container of anhydrous calcium chloride and to record the date and time the procedure is started and completed.

7.6.3.3 Moisture-tight sealant (gun-grade) or sealant tape to secure and seal the cover to the concrete floor.

7.6.3.4 A brightly colored "CAUTION" label to be placed on the plastic cover as a protective warning while the procedure is being conducted.

7.6.4 *Preparation of Apparatus*—Apparatus may be purchased from a proprietary supplier or assembled by the test agency.

FIG. 2 Anhydrous Calcium Chloride Test

7.6.5 *Calibration and Standardization*—None.

7.6.6 *Procedure*:

7.6.6.1 Pour the anhydrous calcium chloride from its container onto the concrete floor in an area small enough so that the calcium chloride can be entirely covered by the plastic canopy.

7.6.6.2 Apply the sealant in a continuous bead to the flanges of the plastic cover and immediately place the canopy over the anhydrous calcium chloride.

7.6.6.3 Press the flanges, with the sealant applied, to the concrete floor making sure that there is an airtight seal between the flanges of the plastic canopy and the concrete.

7.6.7 *Calculation or Interpretation of Results*—After 72 h, remove the plastic canopy and visually examine the anhydrous calcium chloride. If there is negligible moisture, there will be no visible change in the anhydrous calcium chloride. A small amount of moisture will cause the anhydrous calcium chloride to cake or darken. More moisture will cause drops to form; and, in severe cases, the anhydrous calcium chloride will dissolve.

7.7 *Quantitative Anhydrous Calcium Chloride Test*:

7.7.1 *Summary of Method*—Test moisture emission by measuring the mass of water absorbed by anhydrous calcium chloride ($CaCl_2$) during a specific period of time. A container of anhydrous calcium chloride is exposed to the atmosphere adjacent to a concrete floor under a vapor-retardant cover.

7.7.2 *Significance and Use*:

7.7.2.1 See Section 5.

7.7.2.2 The anhydrous calcium chloride test was developed by the Rubber Manufacturers Association, Inc., in the early 1950's.[16,17]

7.7.3 *Apparatus*:

7.7.3.1 A scale for weighing anhydrous calcium chloride with a minimum resolution of 0.1 g.

7.7.3.2 A transparent, hole-free plastic canopy, square or circular in shape, 70 in^2(450 cm^2) $\pm$ 10% in area, depth greater than the depth of the cylindrical container of anhydrous calcium chloride, and with approximately 0.5 in (12 mm) flanges around the perimeter of the cover.

7.7.4 *Reagents and Materials*:

7.7.4.1 One cylindrical plastic container of anhydrous calcium chloride with a cover area of 6 in^2(40 cm^2) $\pm$ 10%. The anhydrous calcium chloride shall be tape-sealed in the container against moisture or heat-sealed in an air-tight bag to prevent moisture absorption (Fig. 2). The mass of the container, the anhydrous calcium chloride, and the tape seal shall be 30 g $\pm$ 10%.

[16] The Rubber Manufacturers Association (RMA) is no longer involved with floor coverings and has no records regarding the history of this procedure, although its origins are widely attributed to the RMA. It has been widely used and accepted by the flooring industry since the early 1950's, and quantitatively measures the rate of moisture transmission through or out of a concrete slab.

[17] The World Floor Covering Association describes this as "the only objective quantified test that is practical to run" (Moisture Guidelines for the Floor Covering Industry). The Resilient Floor Covering Institute "subscribes to the use" of this procedure (Addressing Moisture Related Problems Relevant to Resilient Floor Coverings Installed Over Concrete). The Carpet and Rug Institute (CRI 104 - 1994, Standard for Installation of Commercial Textile Floorcovering Materials) states, "All concrete floors should be tested to determine the moisture emission rate by utilizing a calcium chloride moisture test kit available from installation supplies and accessories distributors."

7.7.4.2 A pressure sensitive label to be used to identify the location of the container of anhydrous calcium chloride and to record the location and the date, time the procedure is started and completed, and its mass.

7.7.4.3 Moisture-tight sealant (gun-grade) or sealant tape to secure and seal the canopy to the concrete floor.

7.7.4.4 A brightly colored "CAUTION" label to be placed on the canopy as a protective warning while the procedure is being conducted.

7.7.5 *Preparation of Apparatus*:

7.7.5.1 Apparatus may be purchased from a proprietary supplier or assembled by the test agency.

7.7.6 *Calibration and Standardization*:

7.7.6.1 The scale shall be re-calibrated prior to each procedure sequence.

7.7.6.2 Weighing shall be done with the same scale for each procedure sequence.

7.7.7 *Procedure*:

7.7.7.1 If the anhydrous calcium chloride is separately packaged, pour it into the container without spilling the contents. Using a scale, determine the mass of the container of anhydrous calcium chloride, the tape (if used) to seal the container, and the cover label to the nearest 0.1 g. Record the value. If sealing tape is used, save the tape to reseal the container after the procedure is completed.

7.7.7.2 Remove the lid of the anhydrous calcium chloride container, and place it underneath the container on the floor.[18]

7.7.7.3 Measure and record the area under the canopy.[19]

7.7.7.4 Broom, brush, or vacuum the procedure area just prior to placement to remove any dust or debris which could interfere with the sealant bond. Apply the moisture-tight sealant in a continuous bead to flanges of the plastic canopy. If the sealant is tape-type, do not butt-joint; overlap ends to assure there are no gaps. Test for air-tightness by pressing firmly on the center of the canopy. The canopy should resist pressure if properly sealed air-tight. Air-tightness can also be tested by laying strips of tissue paper around the perimeter of the canopy. If the tissues are not disturbed by air movement when the canopy is depressed, it is properly sealed air-tight.

7.7.7.5 On the container cover label record the procedure number, location of the procedure on the floor, the mass, and the date and time the procedure was started.

7.7.7.6 Place the caution label on outside of the canopy as a protective warning, and allow the unit to remain undisturbed for a period of 60 to 72 h.

7.7.7.7 Remove the plastic canopy and immediately place the top back on the anhydrous calcium chloride container. Reseal the container with the original sealing tape. Record on the cover the date and time the procedure was completed.

7.7.7.8 Do not spill any of the anhydrous calcium chloride from the container. If any is spilled, the procedure must be re-run with a new pre-weighed moisture test unit.

7.7.7.9 Weigh the sealed container at the procedure site, along with the tape used to seal it. Record the mass on the label on the container cover, and determine the mass gain.

7.7.8 *Calculation or Interpretation of Results*:

7.7.8.1 Compute moisture emission (ME) as follows

$$ME = \frac{24000\Delta M}{453.6A \cdot T} = 52.91\Delta M/(A \cdot T) \quad (1)$$

where

ΔM = mass gain of anhydrous $CaCl_2$ in g
A = contact area of $CaCl_2$ on concrete in ft^2
T = exposure time in h
ME = moisture emission in lb/(1,000 $ft^2 \cdot 24h$)

7.7.8.2 To convert results to SI, multiply by 56.51 to obtain $\mu g/(s \cdot m^2)$.

7.7.8.3 To calculate ME in SI units, use the formula ME = $\Delta M / A \cdot T$, where ME is in g, T is in s, and A is in mm^2.

7.7.8.4 If the plastic canopy is found punctured, the anhydrous calcium chloride in the container has a continuous crust, liquid water is present in the container, or the anhydrous calcium chloride crystals are dissolved, computations will probably indicate an excessively high moisture level but with a higher margin of error than with lower levels of moisture.[20]

7.7.8.5 Most flooring product manufacturers recommend that the maximum ME considered acceptable for moisture-sensitive flooring systems is 3.0 lb/[1,000 $ft^2 \cdot$ 24 h] (170 $\mu g/(s \cdot m^2)$, although 5.0 lb/[1,000 $ft^2 \cdot$ 24 h] (280 $\mu g/(s \cdot m^2)$) is considered acceptable for some products.[21]

7.8 *Primer or Adhesive Strip Test*:

7.8.1 *Summary of Method*—This method uses a sample of the proposed floor finish material primer or adhesive to predict the behavior of moisture-sensitive adhesives.

7.8.2 *Apparatus*—none.

7.8.3 *Reagents and Materials*—flooring adhesive or primer.

7.8.4 *Preparation of Apparatus*—none.

7.8.5 *Calibration and Standardization*—none.

7.8.6 *Procedure*—Place several small patches of adhesive or primer approximately 24 in × 24 in (600 mm × 600 mm) in size on the slab.

7.8.7 *Calculation or Interpretation of Results*—If after the primer or adhesive has been down 24 h it bonds securely to the slab, the resilient material may be installed. If the primer or adhesive can be peeled from the floor using a putty knife, the slab has unacceptable moisture.

[18] Some users of this procedure have advocated placing the container over a $0.05 U.S. coin, washer, or similar spacer. A U.S. $0.05 coin is approximately 0.07 in (2.0 mm) thick by 0.83 in (21.0 mm) diameter. Any coin, washer, or spacer with a thickness greater than 1.5 mm and a diameter less than 25 mm will suffice. Whether or not the use of a spacer affects the results has not been proven, but the consensus of users is that it does not.

[19] Some users of this procedure advocate subtracting the area covered by the anhydrous calcium chloride container if the container is placed directly on the floor rather than over a spacer. Whether or not the subtraction of the covered area affects the results has not been proven, but the consensus of users is that it does not.

[20] For greater accuracy in ascertaining moisture emission above the level of normal acceptability or in diagnosing high levels of moisture emission with a lower margin of error, repeat the procedure at the same location with either a shorter duration (60 h minimum), a larger diameter anhydrous calcium chloride container, or both. If the anhydrous calcium chloride container is approximately 3.5 in (90 mm) in diameter, use approximately 30 g of anhydrous calcium chloride. If the anhydrous calcium chloride container is approximately 5 in (130 mm) in diameter, use approximately 40 g of anhydrous calcium chloride. The purpose is to expose optimum surface area to water vapor.

[21] Armstrong Commercial Flooring, Technical Services Report No. 15, June 1994, recommends 5.0 lb for 1/8 in vinyl composition tile and felt-backed commercial sheet flooring.

7.9 *Hygrometer or Relative Humidity Test*:

7.9.1 *Summary of Method*—Determines moisture emission by measuring relative humidity of atmosphere confined adjacent to concrete floor.

7.9.2 *Significance and Use*:

7.9.2.1 See Section 5.

7.9.3 *Apparatus*:

7.9.3.1 A vapor-retardant canopy and an instrument capable of measuring the relative humidity of a pocket of air trapped above the slab and in contact with the slab. The pocket of air is isolated from the ambient atmosphere within the space where the floor is located by the canopy, and in one of the two variations of the procedure, additionally by thermal insulation. Two forms of apparatus are shown in Fig. 3 and Fig. 4. Type 2 is simpler but less accurate than Type 1.

7.9.3.2 *Apparatus Type 1*—The apparatus shown in Fig. 3 consists of an insulated vapor-impermeable box and a hygrometer or relative humidity (rh) probe for measuring relative humidity to an accuracy of ± 3% rh. The instrument can be a hair, paper, or synthetic fiber hygrometer of the clock-type, or an electronic relative humidity probe.[22] Other forms of apparatus may be suitable but the width of an area shall not be less than 6 in (150 mm), and it is essential that the principles of thermal insulation and vapor barrier be observed. Suitable vapor-barrier materials are sheet metal, glass, or 0.080 in (2 mm) thick acrylic or polyvinyl chloride sheet. The canopy shall have a maximum U-value of 0.18 Btu/($h \cdot ft^2 \cdot °F$) (1.0 W/($m^2 \cdot K$).

7.9.3.3 A simplified version of the apparatus which omits the thermal insulation is shown in Fig. 4. The hygrometer is placed on the slab with a sheet of polyethylene supported by a cylinder sealed to the concrete with tape or sealant.

7.9.4 *Reagents and Materials*:

7.9.4.1 Polyethylene sheet, Specification D 4397, 0.008 in (0.2 mm) minimum thickness.

7.9.4.2 Duct tape.

7.9.4.3 Sealant or sealant tape.[23]

7.9.5 *Preparation of Apparatus*:

7.9.5.1 *Apparatus Type 1*—Seal the canopy firmly to the floor using sealant or sealant tape in a manner that allows readings to be taken without breaking the seal and releasing the trapped pocket of air, and allow sufficient time for the entrapped air to reach moisture equilibrium with the floor. To avoid expensive equipment being left on site, the probe may be removed from the canopy and the hole plugged before the canopy is sealed to the floor. After allowing time to reach equilibrium, the plug is removed, the rh probe inserted promptly, and time is allowed for the enclosed atmosphere to reach equilibrium before readings are taken.

7.9.5.2 *Apparatus Type 2*—Seal the canopy firmly to the floor using sealant, sealant tape, or duct tape in a manner that allows readings to be taken without breaking the seal and releasing the trapped pocket of air, and allow sufficient time for the entrapped air to reach moisture equilibrium with the floor.

[22] The most detailed information on this test comes from British Standards Institution (BSI) BS 5325:1983 British Standard Code of Practice for Installation of Textile Floor Coverings and BS 8203:1987 British Standard Code of Practice for Installation of Sheet and Tile Flooring.

[23] A gun-grade sealant or tape-type sealant can be used.

7.9.6 *Calibration and Standardization*—As the accuracy of a hygrometer can drift with time or in transit it may need to be re-calibrated frequently. The accuracy of the hygrometer or rh probe at 75% rh may be checked by sealing it in a dessicator or humidity cabinet over a saturated solution of analytical or general purpose reagent grade sodium chloride, at a constant temperature of 68 ± 4°F(20 ± 2°C) for at least half an hour. The atmosphere above the solution will be 75 % over the complete temperature range in which the instrument is likely to be used.

7.9.7 *Conditioning*:

7.9.7.1 See Section 5.

7.9.7.2 To minimize the time required for the instrument to be in position on the floor, the following technique can be applied. Cover the positions to be measured with vapor-retardant plastic sheet not less than 3 ft by 3 ft (1 m by 1 m) taped to the floor at their edges. Leave in position for at least 7 days. After removing the plastic sheet, immediately seal the instrument to the center of the covered area.

7.9.7.3 Turn off any artificial aids used for accelerating drying of any construction components at least 4 days before final readings are attempted.

7.9.7.4 Allow at least 72 h to elapse after sealing the canopy to the floor before taking the first reading. Equilibrium can be assumed when two consecutive readings taken at 24-h intervals show no change.

7.9.7.5 For slabs thicker than 8 inches (200 mm), more than one week may be required before moisture equilibrium is established. To prevent edge effects on thick slabs, the area for 5.4 ft^2(0.5 m^2) surrounding the instrument shall be covered with a plastic sheet during the procedure.

7.9.8 *Procedure*—Record relative humidity indicated by hygrometer or probe.

7.9.9 *Calculation or Interpretation of Results*—Experimental evidence has shown that when moisture has evaporated from the coarse pores of concrete, the relative humidity falls to 80 %. If allowance is made for errors in determining the relative humidity, it is reasonable to recommend that the concrete be considered acceptable, and installation of resilient and other moisture-sensitive flooring attempted, only when the relative humidity falls to 75 % or less.

8. Reports

8.1 Prepare written report of procedure, indicating the following:

8.1.1 Description of procedure, including reference to procedures described in this practice.

8.1.2 Date and time (to the nearest ¼ h) of procedure (start and stop).

8.1.3 Location of each procedure marked on a floor plan.

8.1.4 Temperature and humidity at start and completion of procedure.

8.1.5 Temperature and humidity range of normal operating environment of building interior (if known), and source of information.

8.1.6 Results of procedure.

8.1.7 Floor finish manufacturer's moisture-related requirements, if any, and reference for source of information.

8.1.8 Analysis of results, and conclusions

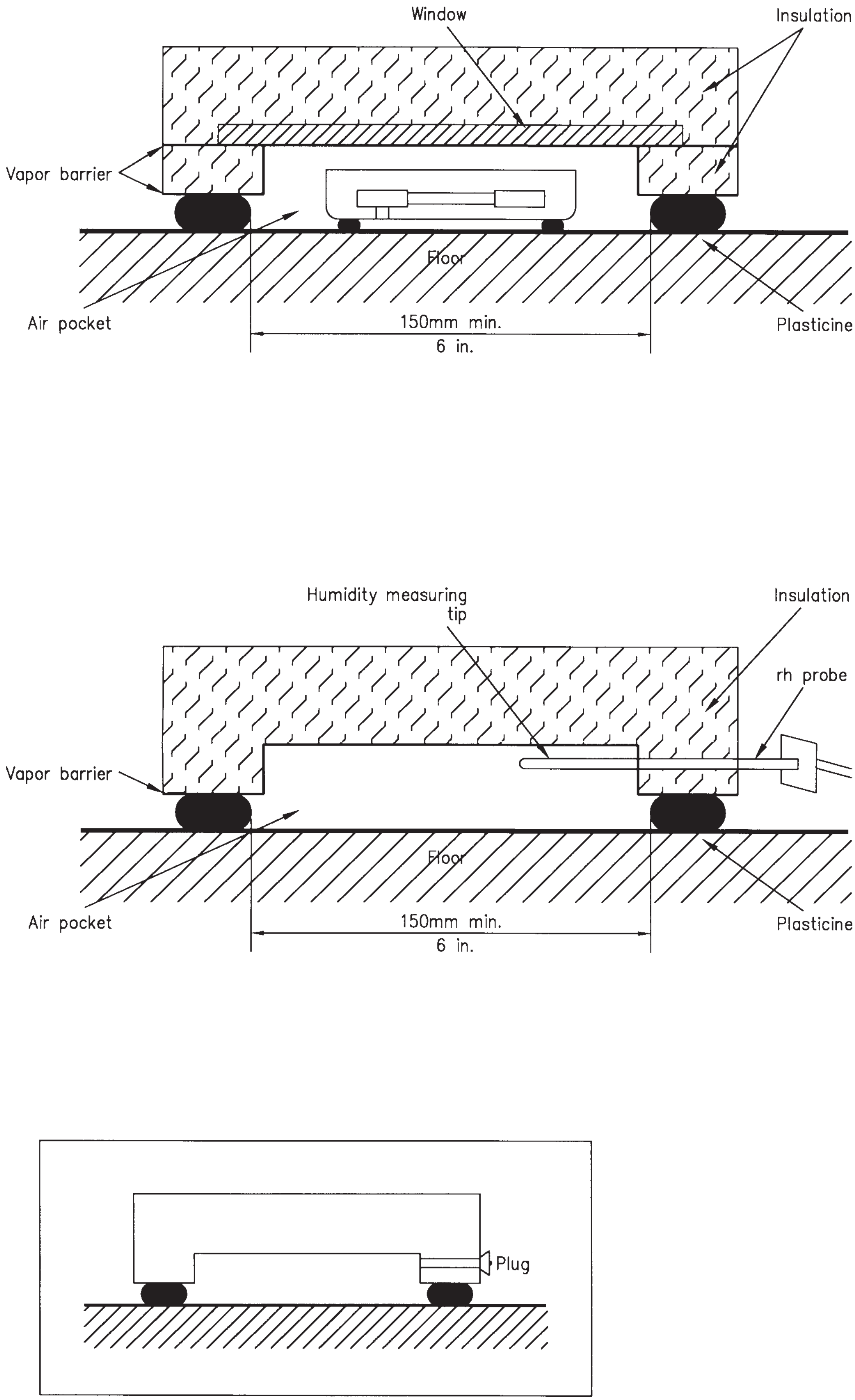

FIG. 3 Hygrometer Test Apparatus

FIG. 4 Type 2 Hygrometer Test Apparatus - Hygrometer is placed on slab below polyethylene tent. In this procedure, no moisture was visibly discernible, but hygrometer reading was 92% relative humidity – too much moisture for resilient flooring installation (Photo: Kentile Floors, Inc.)

8.2 Specifically indicate any unacceptable conditions observed or determined and source of criteria used.

9. Precision and Bias

9.1 The precision and bias has not been established for any of the procedures included in these practices.

10. Keywords

10.1 adhesives; carpet; concrete; floor; moisture; moisture-sensitive; moisture tests; resilient flooring; water; water vapor

APPENDIX

(Nonmandatory Information)

X1. EFFECTS OF MOISTURE

X1.1 Introduction

X1.1.1 The effect on floor coverings from residual moisture in concrete slabs or moisture passing through concrete slabs from underlying soil has been understood and documented since the early 1950's when the RMA (Rubber Manufacturers Association) developed a moisture test method widely adopted by the flooring industry.[24]

X1.1.2 Concrete floors may appear dry from a visual examination but actually have a deleterious level of water vapor in, emitting from, or passing through a slab.

X1.2 *Adverse Impacts*

X1.2.1 Excessive water or water vapor in or emitting from concrete slabs can result in the following adverse impacts:

X1.2.1.1 Adhesive failure.

X1.2.1.2 Failure of paints or coatings to dry, cure, or coalesce.

X1.2.1.3 Distortion (curling, warping, blistering), discoloration, and deterioration of flooring products.

X1.2.1.4 Delamination of coatings.

X1.2.1.5 Spalling and cratering of concrete surfaces. As moisture emits from or passes through a slab, it can carry with it alkaline salts from the ground or the concrete itself which are left behind as the water evaporates. The vapor from salt-bearing ground water is incapable of carrying salts through the concrete, but alkaline salt can build up cyclically at the top of the slab profile due to chemically-pure vapor attracting salts through osmosis.

X1.2.1.6 Deterioration of flat electrical cable.

X1.2.1.7 Fungal growth and odors.

X1.3 *Acceptable Level of Moisture*

X1.3.1 The limitation on the moisture content or level of water vapor emitting from concrete should be dictated by or confirmed with flooring product manufacturers. Substrates should be tested to ascertain moisture conditions before moisture sensitive flooring materials or adhesives are installed. Typical limits or ranges are as follows:

X1.3.1.1 Using Test Method D 2216, moisture content should be between 2.5 and 4.5% for floor covering products. Paint and coating system manufacturers typically recommend less than 10% moisture content

X1.3.1.2 Relative humidity in concrete pores or in the atmosphere of a chamber sealed over concrete should be less than 75%.

X1.3.1.3 Most flooring product manufacturers recommend that the maximum vapor emission considered acceptable for moisture-sensitive flooring systems, as measured by a quantitative anhydrous calcium chloride test, is 3.0 lb/ [1,000 ft^2· 24

[24] Resilient Floor covering Institute (RFCI) Addressing Moisture Related Problems Relevant to Resilient Floor Coverings Installed Over Concrete (Rockville, MD: Resilient Floor Covering Institute, November 1995) p. 6

hours] (170 μg/(s·m^2)), although 5.0 lb/[1,000 ft^2· 24 hours](280 μg/(s·m^2)) is considered acceptable for some products.[25]

X1.4 *Design and Construction-Related Sources of Excessive Water in Concrete Floors*

X1.4.1 *Artificial sources* are typically caused by construction or operation of a building, such as:

X1.4.1.1 *Irrigation*—Mitigate by considering planting that requires low water use and minimizing watering. Exterior grading should provide good runoff or percolation.

X1.4.1.2 *Service conditions*, such as frequent floor cleaning wash-downs. Mitigate by modifying maintenance requirements or providing a waterproof barrier between finish and slab.

X1.4.2 *Natural sources* are those that existed at the site prior to construction but may be exacerbated by the design of the building or the construction process. Natural sources include:

X1.4.2.1 Poor exterior drainage and naturally occurring ground water from a permanent or seasonal high water table. There should be no hydrostatic pressure against the bottom of a concrete slab with moisture-sensitive finishes. Mitigate by providing adequate exterior drainage (grading exterior slopes away from buildings). Rainwater leaders should be piped to storm drains or to dispersal areas away from building. Subdrains can be installed to remove water from under a slab and piped to locations away from buildings by gravity or pumping.

X1.4.2.2 Normal moisture conditions of soil beneath slabs. It is not unusual for the soil below a concrete slab to have a permanently high water table or water vapor content due to capillary flow of water from the water table or lateral flow from the exterior of the building. Mitigate by:

(a) (a) Installing a capillary break of crushed or river-run rock beneath concrete slab (see Practice E 1643 Appendix).

(b) (b) Installing a vapor retarder beneath concrete slab (see Practice E 1643 Appendix).

X1.4.3 *Design and Construction sources*:

X1.4.3.1 Residual water in or below the slab remaining from the construction process can result from water retained below the slab when a sand or crushed rock filled is used between the concrete and a vapor retarder. Whether or not this fill is necessary for proper concrete curing is controversial (see Guide E 1643 Appendix).

X1.4.3.2 Low permeance concrete is desirable for several reasons. It dries quicker, it reduces the flow of vapor (if a vapor retarder is breached or not installed), and it is less hygroscopic. A water-to-cement ratio of approximately 0.22 to 0.25 is required for complete hydration of cement. Typical concrete mix designs may range from a water-to-cement ratio of 0.35 to 0.65. The excess of mixing water not required for cement hydration must be allowed to evaporate prior to the placement of moisture-sensitive floor finishes. To avoid excessive permeance, water-cement ratios should be between 0.45 and 0.50 by weight. Mixes should be designed with compressive strength of 3,000 psi (20 MPa) or more and slumps between 3 and 4 in (75 mm - 100 mm) by using water reducing admixtures and appropriate cement-aggregate ratios. Proper curing resulting in complete hydration of cement is also required to achieve low permeance.

X1.4.3.3 When concrete is excessively permeable, moisture may accumulate by hygroscopicity. Highly permeable concrete may attract moisture from the atmosphere during periods of building occupancy inactivity or when the interior environment is temporarily or permanently left unconditioned, for example, in school buildings during summer recess.

X1.4.3.4 Cracks, joints, and voids will allow increased moisture transmission regardless of the permeance of concrete. Only an effective vapor retarder, properly installed below a slab on or below grade can mitigate the potentially adverse effects of low-permeance concrete or cracks, joints, and voids in high-permeance concrete.

X1.5 *Drying Time*:

X1.5.1 The time required for residual water in slabs to dry out sufficiently in order to not adversely affect floor coverings and finishes typically ranges from six weeks to six months. This drying process is a function of the relative humidity and temperature environment inside a building which, in turn, influence the rate of vapor transmission through and out of the concrete. The rate of vapor transmission increases with an increased vapor pressure difference between the voids in the concrete and the air around the slab.

X1.5.1.1 The vapor pressure of air can be determined from Fig. X1.1 by knowing the relative humidity and temperature conditions. For example, to dry a slab, the movement of moisture must be from the concrete to the air. If the bottom of the concrete has an environment of 100% relative humidity and 70°F (21°C) temperature, then the vapor pressure of air within the concrete is about 0.36 lb/in^2(2.5 kPa). Inside the room, the relative humidity may be 60% and temperature 80°F (26.7°C), which produces a vapor pressure of air of 0.29 lb/in^2(2.0 kPa). High pressure moves to low pressure; therefore, the pressure difference of 0.07 lb/in^2(0.5 kPa) is the driving force of moist air moving from the concrete to the room. To force dry the concrete, it is more desirable to lower the relative humidity in the room than to raise the temperature. If any of the above conditions exist after the floor covering is installed, then the moisture becomes trapped under the covering and condenses, unless the covering itself allows the vapor to pass.

X1.5.2 Concrete ceases to cure once the internal humidity drops below approximately 80%. The actual drying time for concrete slabs may vary, depending on the relative humidity and temperature environment inside the building, the type of curing compound used, whether a bond-breaking compound was used, such as is used in tilt-up construction; whether an antidusting compound was used; the amount of troweling; and the type of aggregate used.

X1.5.2.1 Some curing compounds applied to the slab surface to retard moisture dissipation oxidize and wear off in about two weeks, but others such as wax-based products have to be worn off. Any type of curing compound may be harmful to adhesion of certain finishes, but if curing compounds are

[25] Armstrong Commercial Flooring, Technical Services Report No. 15, June 1994, recommends 5.0 lb for 1/8 in vinyl composition tile and felt-backed commercial sheet flooring.

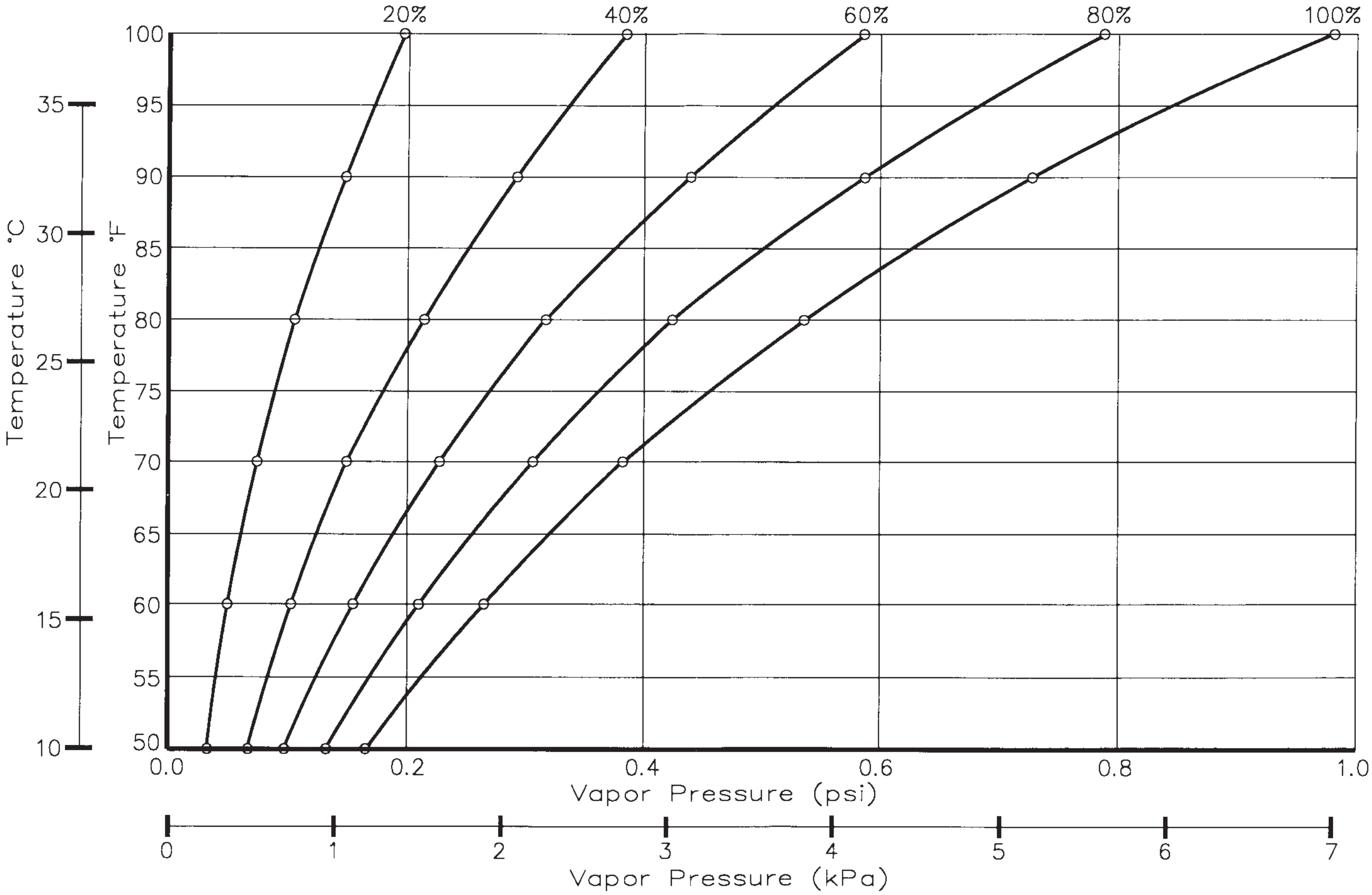

FIG. X1.1 Vapor Pressure of Moisture in Air at Different Temperatures and Relative Humidities. (Source: Ashok Kakade)

compatible with finishes, those that are water or resin based and which oxidize will result in earlier slab drying.

X1.5.2.2 More troweling may mean longer drying time.

X1.5.2.3 Using cinder, pumice, and other lightweight aggregates may cause concrete to dry slower. Aggregates conforming to Specification C 33 are less permeable and produce less hygroscopic concrete than aggregated conforming to Specifications C 330 or C 332. Aggregates conforming to Specification C 332 are not recommended.

X1.5.2.4 For above-grade slabs, some authorities believe the underside of structural metal composite deck components or permanent metal form liners should be perforated to permit the free evaporation of moisture, although this could pose a problem if the environment below a slab has a higher humidity than the environment above the slab.

X1.5.2.5 The Carpet and Rug Institute advises that at least 90-120 days are to be allowed for a concrete slab to cure and reach an acceptable dryness.[26]

X1.5.2.6 The World Floor Covering Association advises: "It has been said that 28 days is required for on-grade or below-grade slabs to "dry" out enough for flooring. This statistic, however, is greatly influenced by a number of variables and should not be used as a criterion as to whether or not it is safe to install a flooring. Above grade slabs poured in metal pans take significantly longer to "dry" and have been known to require several months to well over a year to be safe to install upon."[27]

X1.5.2.7 The Resilient Floor Covering Institute warns that a concrete floor must be allowed to cure and dry for a minimum of six weeks before it is acceptable to install resilient floor coverings.[28]

X1.5.2.8 The Portland Cement Association suggests: "The drying period required will vary with environmental conditions, type and thickness of concrete, and location of the slab. For example, slabs on ground require longer drying periods than suspended slabs. Usually, several months of drying are required after the moist cure period. (Several manufacturers recommend that concrete be at least 60 days old before their floor covering is installed.) Lightweight concrete may require a longer drying period than normal-weight concrete."[29]

[26] CRI 104-1994, Standard for Installation of Commercial Textile Floorcovering Materials (Dalton, GA: The Carpet and Rug Institute, 1994) p. 7

[27] Moisture Guidelines for the Floor Covering Industry (Anaheim, CA: World Floor Covering Association, undated but received August 1995)

[28] Resilient Floor Covering Institute (RFCI) Addressing Moisture Related Problems Relevant to Resilient Floor Coverings Installed Over Concrete (Rockville, MD, Resilient Floor Covering Institute, November 1995) p. 5

[29] Steven H. Kosmatka, "Floor-Covering Materials and Moisture in Concrete", Concrete Technology Today (Skokie, IL: Portland Cement Association, September, 1985) pp. 4-5. (Appendix E)

X1.6 Post-Construction Mitigation

X1.6.1 *Reducing Sub-Grade Moisture*:

X1.6.1.1 *Exterior drainage*—When poor exterior drainage is a contributing factor to excessive concrete moisture, mitigate by reducing irrigation watering, checking for and repairing irrigation leaks, providing better runoff, or installing exterior sub-drains.

X1.6.1.2 Plumbing leaks can raise the moisture content of subsoils or a sand or crushed rock layer beneath a slab. Mitigate by locating and repairing leaks.

X1.6.2 *Reducing vapor transmission*:

X1.6.2.1 Post-construction application of surface treatments may reduce vapor emission to acceptable levels. In order to be effective, treatments must reduce moisture emission to tolerable levels while not resisting pressure so much as to result in spalling. Commercially available treatments typically include systems incorporating one or more of the following:

(a) Acrylic or styrene-butadiene (SBR) polymer-modified cementitious overlays, some with fibrous inter-layers designed to disperse moisture from areas of relatively high emission to areas of relatively low emission.

(b) Water-based epoxies.

(c) Sodium silicates.

(d) Potassium silicates.

X1.6.3 Substituting a more moisture tolerant finish, such as carpet with a permeable backing for wood or vinyl.